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Human identification

HOW USEFUL ARE THE PARANASAL SINUSES FOR HUMAN IDENTIFICATION?

O quão úteis são os seios paranasais para a identificação humana?

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ABSTRACT

The paranasal sinuses have long attracted anatomical and clinical interest due to their complex morphology, variable development, and intimate relationship with craniofacial structures. Historically described since the Renaissance, these air-filled cavities have progressively gained relevance in forensic sciences, particularly in human identification. The present opinion paper addresses the topic substantiating and reinforcing the usefulness of the paranasal sinuses as tools for comparative and reconstructive human identification. More specifically, the developmental, anatomical, and radiological characteristics of the maxillary, frontal, ethmoid, and sphenoid sinuses are approached with emphasis on forensic analysis. Current evidence regarding their morphological and morphometric assessment is summarized to highlight that the vast literature available about the forensic applicability of the paranasal sinuses endorses these structures for comparative human identification of single cases, given their highly distinctive morphology, while for reconstructive procedures, such as sex and age estimation the paranasal sinuses, more specifically the frontal and maxillary sinuses, have been considered potential adjuvant tools, especially when other more reliable anthropological parameters are not available.

KEYWORDS

Forensic dentistry; Paranasal sinuses; Human identification.

INTRODUCTION

The study of the paranasal sinuses gained attention during the Renaissance and was later intensified by anatomists, such as Nathaniel Highmore¹. Over time, anatomy textbooks began to include a more detailed description of these structures. The paranasal sinuses are distributed bilaterally in the skull and arranged pairwise into the

bones that derive their names². They communicate with viscerocranium structures through channels and ostia. Internally, they are covered by a mucous membrane. The present work presents an opinion about the forensic applicability of the maxillary, frontal, ethmoid and sphenoid sinuses for reconstructive and comparative human identification.

Morphological aspects

The maxillary sinuses are the first paranasal sinus to form, beginning in the third month of pregnancy. Throughout its development, this sinus expands in all directions, giving it an overall pyramidal shape^{3,4}. The largest of the four paranasal sinuses, the maxillary sinuses are air-filled cavities in the maxilla located on both sides of the nasal cavity. These sinuses have particular importance given the drainage of secretions to the nasal cavity^{4,5}, also because of their close anatomic relationship with the maxillary teeth.

The frontal sinuses usually appear pneumatized only after birth and is the last to develop among the paranasal sinuses. The frontal sinuses are two cavities located between the anterior and posterior surfaces of the frontal bone, behind the superciliary arches. They are normally separated by an intersinus septum, and its form, number of lobes and septa are highly variable⁶. Drainage is to the middle nasal meatus⁷.

The ethmoidal cells/sinuses are located between the orbit and the nasal cavity and are displayed as a complex structure composed of multiple small air cells separated by thin bony walls. They are bounded laterally by the lamina papyracea, superiorly by the fovea ethmoidalis, posteriorly by the sphenoid body, and anteriorly by the lacrimal and frontal bones. The basal lamella divides the ethmoidal cells into anterior and posterior groups. The anterior ethmoidal cells drain into the middle nasal meatus, whereas the posterior ethmoidal cells drain into the superior or supreme meatus^{4,8}.

The most posterior of the paranasal sinuses are the sphenoid sinuses, which are cuboid-shaped cavities found inside the sphenoid bone. The ethmoidal cells in front, the clivus behind, and the intersinus septum in the center serve as important anatomic landmarks to detect these structures. The sphenoidal recess, which joins the superior nasal meatus, receives the drainage from the sphenoid ostium, which is located on the anterior wall of the SS. Between the ages of 6 and 12, these sinuses show important expansion patterns within the bone^{4,9,10}.

Forensic applications

The scientific literature behind the forensic applications of the morphological and morphometric assessment of paranasal sinuses is vast of studies on the frontal sinuses and maxillary sinuses¹¹. The former because of their distinctive morphological pattern between individuals, and the latter also because of the frequent registration of these sinuses in maxillofacial imaging, such as panoramic radiographs and cone beam computed tomography.

Regarding the frontal sinuses, an additional advantage is considered in forensic practice, which is their location into the highly-resistant frontal bone – making these structures possibly assessable even in charred bodies. A pioneering description of the forensic application of the frontal sinuses came from Zuckerkandl (1895)¹² who noted their evident asymmetry. Since then, the frontal sinuses have been advocated as potential resources for reconstructive human identification, namely via the estimation of sex and age¹³⁻¹⁵.

However, it is because of the distinctive aspect of the frontal sinuses' morphology that the main application of these structures is in comparative human identification, especially by means of radiological analysis¹⁶⁻²⁰. This process involves obtaining suitable *antemortem* radiographs (usually provided by relatives of the victim, and health care professional and hospitals) and postmortem radiographs taken by forensic practitioners in similar techniques. A visual comparison is then performed, focusing on the consistency of morphological features. Evident inconsistencies are also relevant since they can lead to exclusions – an important phenomenon, in this context, is frontal sinus agenesis.

The maxillary sinuses' forensic applicability has much to do with their recurrent registration in dental and medical imaging. The increasing use of advanced imaging techniques like computed tomography (CT) and magnetic resonance imaging (MRI) has further supported more accurate assessments of the maxillary sinuses. These modalities not only improve the *antemortem* resources with high-tech solutions and optimal images but, when available postmortem, they provide alternatives for necroscopic registration. This is the case of virtual autopsy, where minimally invasive equipment is employed to register the deceased's soft and hard tissue²¹.

Studies have been conducted to estimate sex and age from the maxillary sinuses and demonstrated so far have that these structures can be auxiliary to help reconstruct the biological profile¹¹. A recent

umbrella review demonstrated accuracy metrics pooled between systematic reviews between 60-80% to distinguish males and females (with the former having bigger sinuses than the latter), for instance. This scenario could suggest that at least one in every five sex estimates based on the maxillary sinus would be incorrect. For comparative human identification, these sinuses can appear fully registered in antemortem panoramic acquisitions or partially visible in periapical radiographs. Important distinctive features to be considered include the inferior contour of the sinuses' limit, which can be irregular over the root of the permanent maxillary posterior teeth. Moreover, the maxillary sinuses can show alveolar expansions, often called pneumatization, which may display an even more unusual morphological appearance.

Evident scientific gaps exist on the assessment and applications of the sphenoid and ethmoid sinuses for human identification¹¹. This could be explained by the position of the sphenoid sinus posteriorly located and above the base of the skull – an area that is not examined in the dental routine, for instance, and by the complexity of the labyrinth-like arrangement of the ethmoidal cells. *Antemortem* data registering the latter has become more prevalent with the implementation of large field-of-view cone beam computed tomography for the examination of the middle third of the viscerocranium. This phenomenon will soon require more advanced knowledge of forensic dental experts about the radiographic anatomy of the human skull. Additionally, it will demand

technical skills for three-dimensional segmentations and comparisons using image navigation software.

What must not be ignored is the fact that paranasal sinuses' applications for human identification should explicitly follow the operational protocols adopted in each jurisdiction. In mass disasters, for instance, the International Criminal Police Organization (INTERPOL)²³ advocates the use of secondary means for human identification, which are able to screen the target population for potential candidates before jumping to primary means. This procedure of narrowing lists of missing persons has been useful to speed up and add another scientific and technical layer to the complex process of disaster victim identification. In this context, the paranasal sinuses could be valuable to contribute with sex and age estimation, also with distinctive identifying features (such as agenesis or major pneumatization), whenever applicable. Based on current evidence and the protocol itself, this approach could naturally be auxiliary helping further identification through primary means, namely friction ridge, dental and genetic analyses.

In other scenarios and jurisdictions, the paranasal sinuses could assume a more central role in the human identification process depending on the availability of antemortem and postmortem records. In Brazil, for example, the use of paranasal sinuses as identifying parameters can be considered case-by-case. E.g. in single-victim closed scenarios, the use of frontal sinuses for comparative human identification has been adopted and

validated by scientific literature¹⁶⁻¹⁸. Several methods exist to this end, but the morphometric bidimensional analysis proposed by Ribeiro (2000)²³ is the most widespread. The method is user-friendly despite requiring a level of background in maxillofacial radiology, anatomy and software for image visualization. It involves tracing a baseline tangential to the superior margins of the orbits, followed by perpendicular lines marking the maximum lateral limits of the frontal sinuses and the highest points of the right and left sinuses. From these lines, four distances can be traced: the total width of both sinuses, the distance between the highest points of the right and left sinuses, and the distances from each lateral sinus limit to its respective highest point²³. Since this method requires posteroanterior radiographic projections and depends of linear measurements, it can be susceptible to distortion (even if teleradiography tends to reduce distortion)²⁴. On the other hand, the method is a viable tool especially for human identification routine in medicolegal units that are not equipped with tomographic imaging, such as most facilities in Brazil. Of course, knowing the method's inherent error rates and how to avoid distortions by setting adequate vertical angles during image acquisition are the first steps to properly approach the frontal sinuses for human identification.

FINAL CONSIDERATIONS

The present study's evidence-based opinion considering existing literature and ongoing research on the forensic

applicability of the paranasal sinuses encompasses:

- The frontal sinuses can be reliable morphological parameters to be assessed for comparative human identification, especially through medical imaging, such as posteroanterior radiographic projections and computed tomography scans, and when presenting distinctive features, such as displaced intersinus septum, agenesis and hypo/hyperplasia. Applications, however, depend on jurisdiction and adopted operation protocol.

- The maxillary sinuses can be useful morphological resources for human identification, especially when fully registered in panoramic projection or computed tomography scans, and especially when presenting evident distinctiveness, such as alveolar extensions or even lesions. Applications, however, depend on jurisdiction and adopted operation protocol.

- The maxillary and frontal sinuses should be carefully approached if used for reconstructive procedures in human

identification. Evidence has backed sex and age estimation with reservations, especially because of the moderate to low accuracy rates. Hence, these morphological parameters should be considered only as adjuvant tools in the reconstructive scenario.

- Given the scarce research evidence about the sphenoid and ethmoid sinuses, applications in practice, mainly for reconstructive approaches, are not advised before validation through original research. For comparative single-case human identification, the use of these paranasal sinuses should be considered case-by-case and based on morphological distinctiveness.

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RESUMO

Os seios paranasais despertam, há muito tempo, interesse anatômico e clínico devido à sua morfologia complexa, desenvolvimento variável e íntima relação com as estruturas craniofaciais. Descritos desde o período renascentista, esses espaços pneumáticos adquiriram progressivamente relevância nas ciências forenses, especialmente no contexto da identificação humana. O presente artigo de opinião aborda esse tema, fundamentando e reforçando a utilidade dos seios paranasais como ferramentas para a identificação humana comparativa e reconstrutiva. Especificamente, são discutidas as características do desenvolvimento, anatômicas e radiológicas dos seios maxilares, frontais, etmoidais e esfenoidais, com ênfase em sua aplicação na análise forense. As evidências atualmente disponíveis sobre suas avaliações morfológicas e morfométricas são sintetizadas para demonstrar que a extensa literatura acerca da aplicabilidade forense dos seios paranasais respalda o uso dessas estruturas na identificação humana comparativa de casos individuais, em razão de sua morfologia altamente distintiva. Por outro lado, em procedimentos reconstrutivos, como a estimativa de sexo e idade, os seios paranasais, mais especificamente os seios frontais e maxilares, têm sido considerados ferramentas adjuvantes promissoras, especialmente quando parâmetros antropológicos mais confiáveis não estão disponíveis.

PALAVRAS-CHAVE

Odontologia legal; Seios paranasais; Identificação humana.

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